# High-Z Divertor Target Development for Alcator C-Mod

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*(R. Nygren presenting)*

## Relation to IPPA goals

Alcator C-Mod

The C-Mod boundary physics program addresses a number of issues listed in the IPPA document.

- 3.1.1 Turbulence and transport (3.1.1.1, 3.1.1.2, 3.1.1.3)
  - Advance the scientific understanding of turbulent transport, forming the basis for a reliable predictive capability in externally controlled systems
- 3.1.4 Plasma boundary physics (3.1.4.1, 3.1.4.2, 3.1.4.3)
  - Advance the capability to predict detailed multi-phase plasma-wall interfaces at very high power- and particle-fluxes.
- 3.3.1 Profile control (3.3.1.4, 3.3.1.5 - low $n_e$ divertor operation)
  - Assess profile control methods for efficient current sustainment and confinement enhancement in the advanced tokamak, consistent with efficient divertor operation, for pulse lengths much greater than energy confinement times.
- 3.4.1 Plasma technologies (3.4.1.3 - Plasma facing components)
  - Develop enabling technologies to support the goals of the scientific program, including methods for plasma measurements, ….; develop plasma facing components….

# C-Mod Boundary physics program

Alcator C-Mod

- Optimize the performance of fusion devices through
  - minimal core impurities (radiation, fuel dilution),
  - maximal first-wall lifetime, power handling
  - divertor design for optimal impurity/neutral compression and pumping

- To those ends we concentrate our research on
  - Edge plasma transport
    - Our primary emphasis because it is the determining factor for heat and particle loadings, impurity sources and transport
  - Neutral dynamics and fueling
  - Impurities

  - Develop predictive capability scaleable to reactor (ITER)

- We also identify and develop hardware and techniques for
  - Heat flux handling & density control

# High heat flux handling & density control

- Important for the success of the C-Mod program
- Supports ITER for high-Z experience

## Status

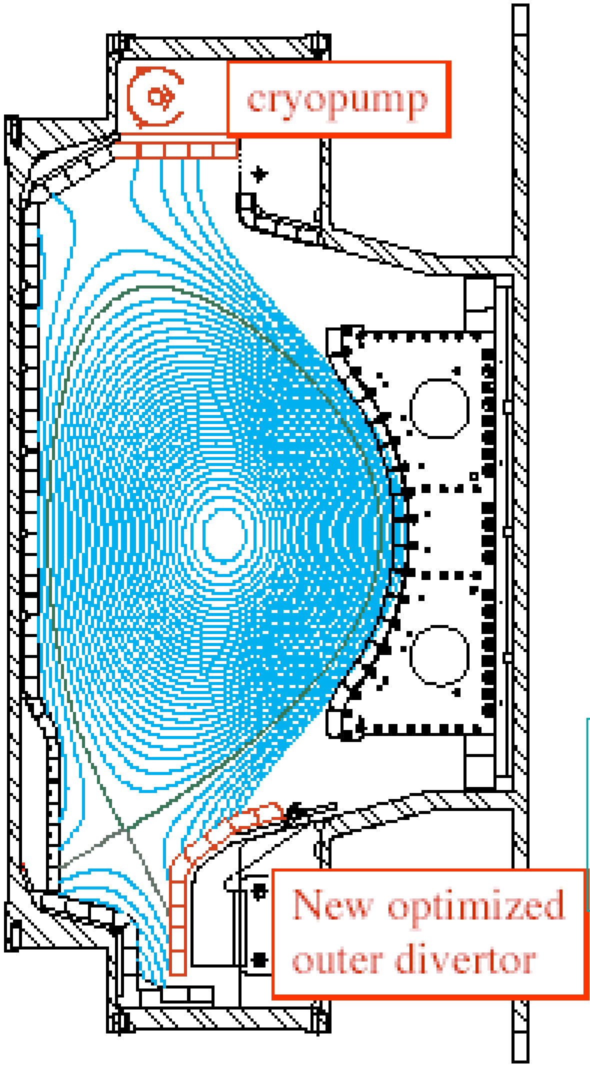
- Presently 0.5 - 1.0 s pulse, 6 MW RF
  - melting at some divertor leading edges (shielded from the core)
- Energy deposited will increase
  - Power increase by ~ x2, 5 seconds
  - $\Delta T^{o} = q_{\perp}\ (W/m^2) \times \gamma_{Mo} \times (t(sec))^{0.5}$
    - $\Delta T$ increases by ~ x4
  - extrapolation => melting at strike points if nothing is done
- No pumping, but H-mode densities might be too high for AT

## Goals/Program

- Develop improved surface temperature monitoring
- Extend divertor heat-handling capability (~x2)
- $\boxed{\text{Test Tungsten-brush tiles}}$
- Extend power dissipation techniques (efficacy, low-$n_e$)
- Cryopump operation

# C-Mod continues to explore new concepts in particle and power control

Alcator C-Mod



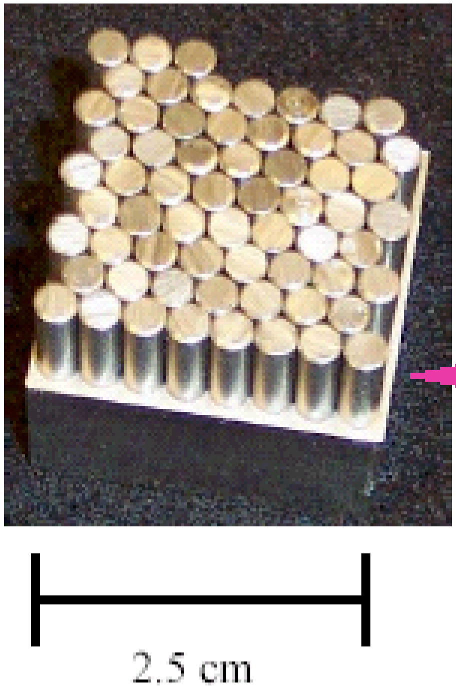

- Based on our experience with SOL transport and neutral dynamics, we will investigate a new combined particle and power control operation…
  - Near double-null operation
  - Heat load to primary divertor
  - Particle pumping to secondary divertor
  - Cryopump on secondary divertor, outer leg
- Why? And what for?
  - Open divertor still 'plugged' by plasma
  - Radial fluxes are high, feeding 2nd divertor
  - Separates power and particle control functions
    - Simplifies each divertor design

- We also plan to use advanced divertor target materials (high Z)
  - Prototype tungsten brush modules (near term)

# Tungsten brush tile development and testing part of the C-Mod program

Alcator C-Mod

Sample C-Mod W-brush tile




- Tungsten brush tiles have been proposed for BPXs
  - shown to handle up to 20 $MW/m^2$ steady state
  - resists melt layer formation
  - no tokamak experience
- C-Mod is working towards W-brush tile installation and testing
  - based on original Sandia design
  - collaboration with Sandia
- C-Mod design aimed at
  - simplified construction and manufacture
  - maximization of W/support interface
- Plans
  - 2 different tile designs being manufactured & tested
  - plan for installation of ~ 5-10 tiles next vacuum break

## Divertor and Edge Physics: Summary

- Our intent is to continue to make fundamental contributions with emphasis on the following :
  - Steady state profile transport analysis to understand
    - Poloidal variations, machine scalings (ITER) -> uncover underlying physics
  - Edge flows importance in core confinement and possibly L/H thresholds
  - Turbulence studies
    - Turbulence relationship to large convective transport
    - Improved images/analyses/scalings/simulations & predictive capability,
    - Control if possible
  - Develop predictive capability for ITER SOL and thus power flows to PFC surfaces
  - Measure and model the 3D aspects of neutral dynamics
  - Characterize impurities at every step in 'lifecycle' - develop 'predictive codes'.
  - Develop separable divertor particle and heat control functions
  - Optimize high-Z first-wall and divertor for long-pulse & heat flux operation

- Providing vital support for overall physics program
  - Advanced Tokamak
  - Burning Plasma